EXERCISE 19

Locating the Planets

Well before Galileo turned his telescope to the heavens in the early 1600s, countless others wondered about those celestial objects that change position in the sky relative to the background of stars. The ability to recognize a planet in the night sky is one of the first skills developed by any astronomer (Figure 19.1). It begins with an understanding of the motions of celestial objects and the proficient use of astronomical charts.

This exercise examines a "working" scale model of the solar system. Using diagrams, you will investigate the movements of those planets visible to the unaided eye that have been observed since antiquity and have given their names to the days of our week.

Objectives

After you have completed this exercise, you should be able to:

1. Explain the observed motion of a planet when it is viewed from Earth.
2. Prepare a scale model of the solar system for a specified date showing the positions of the five planets that can be viewed from Earth without a telescope.
3. Use a diagram of the solar system to estimate the time that a planet will rise and set.
4. Explain the conditions that determine whether or not a planet can be seen on a specified date.

Materials

ruler
colored pencils
calculator

Terms

constellations of the zodiac	period of revolution
	retrograde motion

Figure 19.1 The "red planet" planet Mars as viewed from Earth at night with an unaided eye. (Courtesy of NASA)

A Working Scale Model of the Solar System

Most scale models of the solar system, such as the one you may have constructed in Exercise 18, simply illustrate the planets in a line or do not incorporate the element of planetary motion. To accurately portray the solar system at any given moment involves showing the planets at their correct scale model distance from the Sun as well as placing them in their proper position around the Sun.

Figure19.2 presents the orbits of Earth and Mars as viewed from above the Northern Hemisphere of

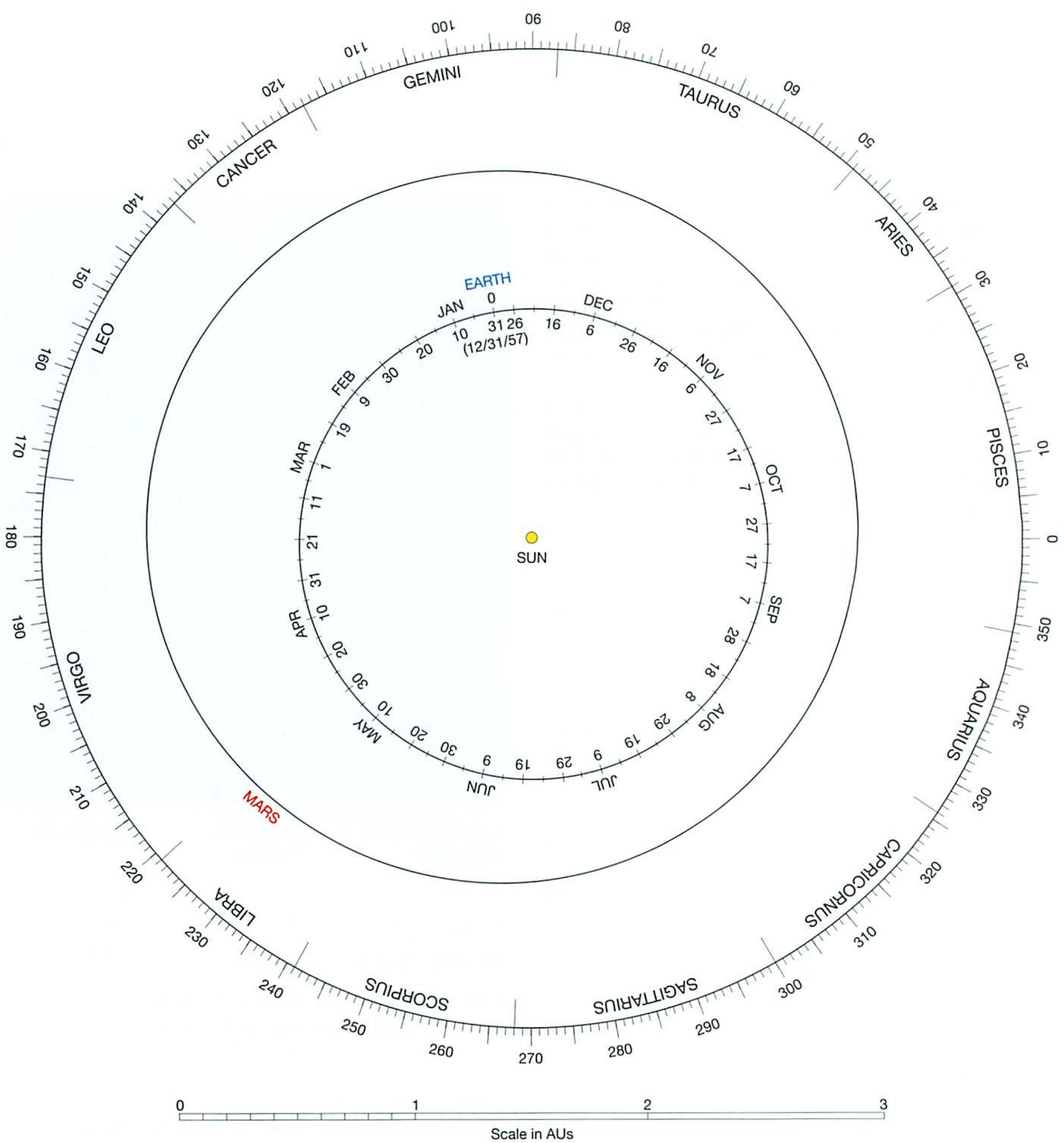

Figure 19.2 The orbits of Earth and Mars to scale as viewed from above the Northern Hemisphere.

Earth. Earth's orbit has been subdivided into the months of the year and select days of each month. The small circle in the center of the figure represents the Sun. Surrounding the orbits is a large circle, marked in degrees, which is used to reference the locations of the planets. Since the planets, Moon, and Sun lie in nearly the same plane, they, when observed from Earth, move along the same region of the sky, called the *zodiac* ("zone of animals"). Indicated on the outer reference circle are the twelve **constellations of the zodiac**, which form the background of stars.

Revolution of the Planets

The **period of revolution** of a planet is directly related to its distance from the Sun (Kepler's third law). The direction of revolution around the Sun is the same for all planets.

On Figure 19.2, draw an arrow on Earth's and Mar's orbit showing their direction of revolution around the Sun. Then answer questions 1–3.

1. Refer to Table 18.1, "Planetary Data," in Exercise 18, and record the *exact* distance from the Sun in AU and the *exact* period of revolution for the planets listed below.

	DISTANCE (AU)	PERIOD OF REVOLUTION
Mercury:	________	____________
Venus:	________	____________
Mars:	________	____________
Jupiter:	________	____________
Saturn:	________	____________

Using the distance scale on Figure 19.2, draw arrows on the figure showing the direction of revolution for Mercury and Venus at their proper scale distances from the Sun.

2. As shown on Figure 19.2, the direction of revolution of the planets in the solar system, when viewed from above the Northern Hemisphere of Earth, is (clockwise, counterclockwise). Circle your answer.
3. Using the information in Figure 19.2 and question 1, write a brief comparison of the periods of revolution of the five planets that are visible from Earth.

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Positioning a Planet Using the Reference Circle

The common reference circle surrounding Figure 19.2 and the data in Table 19.1 (page 272) are used to plot a planet's position around the Sun. Table 19.1 shows the degree location on the common reference circle (Heliocentric Ecliptic Spherical Coordinates, or bearing) of the five planets that are visible from Earth without a telescope for the years 2008–11. The degree indicated is the location of the planet on the first day of the selected month. For example, the position (bearing) of Mercury on the first day of January 2010 is 80 degrees. The following steps are used to determine a planet's position on Figure 19.2.

Step 1: Using Table 19.1, determine the degree location of the planet on the specified date. (*Note:* Simple interpolation of the data in the table can be used to estimate a planet's position on dates other than the first of each month.)

Step 2: Mark the degree location you determine in Step 1 on the 360° reference circle surrounding Figure 19.2.

Step 3: Draw a straight line that connects the center of the Sun (the small circle at the center of Figure 19.2) with the marked degree position from Step 2.

Step 4: To indicate the precise location of Mercury and Venus, measure each planet's scale AU distance from the Sun along the line you drew in Step 3 and place a dot representing the planet at the proper distance on the line. Label each planet with the specified date. For Mars, mark and label the location where its line crosses the planet's orbit. Earth's position is determined by placing a dot on its orbit at the date specified. Due to their greater distances, the positions of Jupiter and Saturn will lie off the page.

4. Using Table 19.1, accurately determine the degree location of the following planets for the dates indicated. (As an example, some of the locations have been done.)

PLANET	MAY 1, 2009	JULY 15, 2010
Mercury:	________	(172°)
Venus:	________	________
Mars:	(342°)	________
Jupiter:	________	________
Saturn:	________	________

5. Using the data in question 4, accurately plot the May 1, 2009, locations of Earth and the five planets that can be viewed from Earth without a telescope on Figure 19.2.

Table 19.1 Degree Locations (Heliocentric Ecliptic Spherical Coordinates)

2008	MERCURY	VENUS	MARS	JUPITER	SATURN
January	308°	183°	96°	272°	153°
February	104	233	111	274	154
March	227	279	124	277	155
April	318	328	138	279	156
May	116	16	151	282	157
June	239	65	164	284	158
July	330	114	178	287	159
August	139	164	191	289	161
September	250	214	206	292	162
October	346	262	220	294	163
November	159	311	236	297	164
December	258	359	251	300	165
2009	**MERCURY**	**VENUS**	**MARS**	**JUPITER**	**SATURN**
January	5°	48°	269°	302°	166°
February	177	98	287	305	167
March	264	144	304	307	168
April	15	194	323	310	169
May	181	242	342	313	170
June	275	291	2	315	171
July	31	339	20	318	172
August	196	28	38	321	173
September	287	78	56	323	174
October	55	126	72	326	175
November	209	177	88	329	176
December	296	225	102	332	177
2010	**MERCURY**	**VENUS**	**MARS**	**JUPITER**	**SATURN**
January	80°	274°	117°	334°	178°
February	222	323	131	337	179
March	302	8	143	340	181
April	93	57	157	342	181
May	225	106	170	345	182
June	316	156	183	348	184
July	112	205	197	351	185
August	237	254	211	354	186
September	331	303	227	356	187
October	135	351	242	359	188
November	248	40	258	2	189
December	343	88	275	5	190
2011	**MERCURY**	**VENUS**	**MARS**	**JUPITER**	**SATURN**
January	156°	139°	294°	8°	191°
February	259	189	313	10	192
March	352	234	331	13	193
April	165	283	350	16	194
May	262	331	9	19	195
June	11	20	28	21	196
July	178	68	45	24	197
August	273	118	62	27	198
September	33	168	79	30	199
October	193	217	94	33	200
November	285	266	108	35	201
December	51	314	122	38	202

(Source: Tabulated coordinates derived from ephemerides computed by NASA's Jet Propulsion Laboratory's *HORIZONS* system.)

Determining in Which Constellation a Planet is Located

A planet is often referred to as being "in" a constellation. The reference is to the particular constellation that is positioned directly behind the planet when that planet is viewed from Earth at its location in its orbit on that same date. The following steps are used to determine in which constellation a planet is located.

Step 1: Using Figure 19.2, make sure the position of Earth is at the same date as the planet's position. Then, beginning at the position of Earth, draw a line that extends through the position of the planet on the same date.

Step 2: For Mercury, Venus, and Mars, extend the line until it intersects the surrounding reference circle and note the constellation that lies in the planet's background.

6. By following the procedure for determining in which constellation a planet is located, determine the constellation in which each of the following planets is observed on May 1, 2009.

PLANET	CONSTELLATION (ON MAY 1, 2009)
Mercury:	(Taurus)
Venus:	
Mars:	

Relative Movement of the Planets

The planets that are farthest from the Sun take longer to complete one revolution than those that are nearest the Sun (Kepler's third law). Therefore, given the same interval of time, planets that are near the Sun will move farther in their orbits and in the sky relative to the background of stars than planets that are at a great distance.

To aid in understanding the effects that different periods of revolution have on the location of planets in the sky, complete questions 7–11.

7. Using the information in question 1, how many revolutions will Mercury complete in one Earth year (365.25 days)? How will this motion influence how we see Mercury from Earth throughout the year?

8. What fraction of a revolution will Jupiter complete in one Earth year? How will this motion influence how we see Jupiter from Earth throughout the year?

9. Using the data in Table 19.1, estimate how many degrees each of the planets visible from Earth without a telescope will move in their orbit over a period of one month.

PLANET	MOVEMENT OVER ONE MONTH
Mercury:	
Venus:	
Mars:	
Jupiter:	
Saturn:	

On Figure 19.2, advance Mercury, Earth, and Mars three months beyond the May 1, 2009, position in their orbits. Place a dot at the new position of each planet and label each with the August 1, 2009, date.

10. Had you been observing Mercury and Mars each night over the three-month period, how would the position of each have changed in the sky relative to the background of stars?

11. Write a brief statement describing how the positions of the planets visible from Earth without a telescope will change in the sky throughout the course of a year.

Retrograde Motion

The fact that Earth periodically overtakes the more distant planets in their orbits makes the motion of the outer planets *appear*, on occasion, to move backward. The apparent backward, or westward, movement of a planet when viewed from Earth is called **retrograde motion**. (*Note:* A similar observation is made when one vehicle passes another going the same direction on a highway. For a period of time, relative to a fixed background, the vehicle being passed *appears* to move backward.)

Figure 19.3 illustrates six equally successive positions of Earth and Mars in their orbits over a period of approximately six months. To illustrate retrograde motion, complete the following steps using Figure 19.3.

Step 1: On Figure 19.3, accurately draw a line connecting Earth to Mars at each of the six positions in the orbits. Extend each line from Mars to the background of stars shown on the figure. Mark the place where each line intersects the background of stars and label it with the number of the position. (*Note:* Positions 1 and 2 have already been done and can serve as guides.)

Step 2: Using a continuous line, connect the six numbered positions on the background of stars in order, 1 to 6.

Use the diagram you have constructed in Figure 19.3 to answer questions 12–15.

12. Describe the apparent motion of Mars, as viewed from Earth, relative to the background of stars.

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13. At any time did Mars actually move backward in its orbit?

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14. Explain the reason for the observed motion of Mars relative to the background of stars.

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15. Assuming, as Ptolemy erroneously did in A.D. 141, that Earth does *not* move in an orbit, but remains stationary as the planets, Sun, and Moon orbit it, how must the observed motion of Mars you described in question 12 be explained?

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Viewing a Planet from Earth

Earth rotates on its axis in a counterclockwise direction when viewed from above the Northern Hemisphere, the reference point of Figure 19.2. Noon is that place on Earth directly toward the Sun, while midnight is on the opposite side from noon. Sunrise and sunset are located respectively between noon and midnight. To observe a planet with the unaided eye, you must be in darkness and on the half of the Earth facing the planet.

The following steps are used to determine the best times for viewing a planet from Earth.

Step 1: On Figure 19.2, indicate the positions of the planets and Earth on the desired date.

Step 2: On Earth, mark the locations of noon, sunset, midnight, and sunrise.

Step 3: Draw a line on Earth that separates the half of Earth *directly* toward the desired planet from the half directly away.

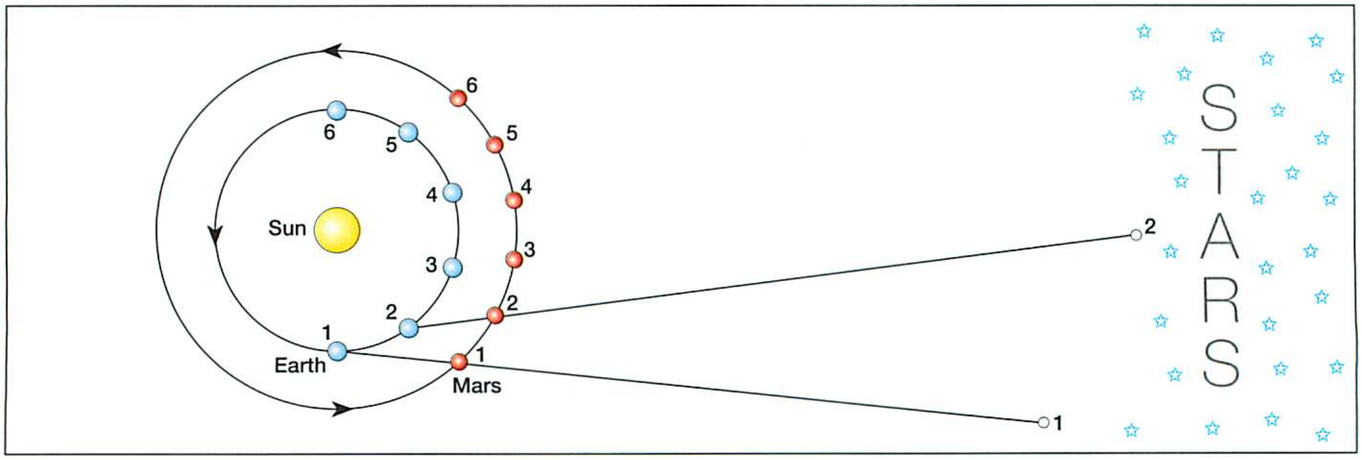

Figure 19.3 Diagram of the Sun, Earth, and Mars for illustrating retrograde motion. (Diagram not drawn to scale.)

Step 4: Keeping in mind that an earthbound viewer must be on the half of Earth facing the planet to see it, note the two places where the line from Step 3 crosses the times indicated on Earth. These will be the times the planet is first visible (*rises*) and when it becomes no longer visible (*sets*).

Use the May 1, 2009, positions of the planets plotted on Figure 19.2 (questions 4 and 5) to answer questions 16–18.

16. Using the steps outlined above, estimate the May 1, 2009, approximate rising and setting times for each of the following planets.

PLANET	RISE	SET
Venus:	______	______
Mars:	______	______
Saturn:	______	______

17. On May 1, 2009, what are the best times to observe the following planets with the unaided eye?

Venus: ____________________________

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Mars: ____________________________

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Saturn: ____________________________

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18. On May 1, 2009, Mercury is visible in the (evening, morning) sky and the best time to observe Jupiter is (before, after) midnight. Circle your answers.

The Solar System Today

Using Table 19.1 and what you have learned, on Figure 19.2 accurately construct a scale model of the solar system for today's date (or the date specified by your instructor) showing the positions of the five planets visible from Earth without a telescope. After you have completed your model, answer question 19.

19. Using the positions of the planets for today's date (or the date specified by your instructor) plotted on Figure 19.2, write a brief description of each planet's visibility from Earth. Indicate when each will rise and set and, when appropriate, the best time(s) to observe the planet.

Mercury: ____________________________

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Venus: ____________________________

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Mars: ____________________________

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Jupiter: ____________________________

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Saturn: ____________________________

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Locating the Planets on the Internet

Continue your analysis of the topics presented in this exercise by completing the corresponding online activity on the *Applications & Investigations in Earth Science* website at http://prenhall.com/earthsciencelab

Notes and calculations.

Locating the Planets

Date Due: ______________________

Name: ______________________

Date: ______________________

Class: ______________________

After you have finished Exercise 19, complete the following questions. You may have to refer to the exercise for assistance or to locate specific answers. Be prepared to submit this summary/report to your instructor at the designated time.

1. In Figure 19.4 prepare a diagram of the solar system showing the relative positions of the planets Mercury through Mars for today's date (or the date specified by your instructor). View the solar system from above the Northern Hemisphere of Earth. Show the planet's locations as accurately as possible and label each.

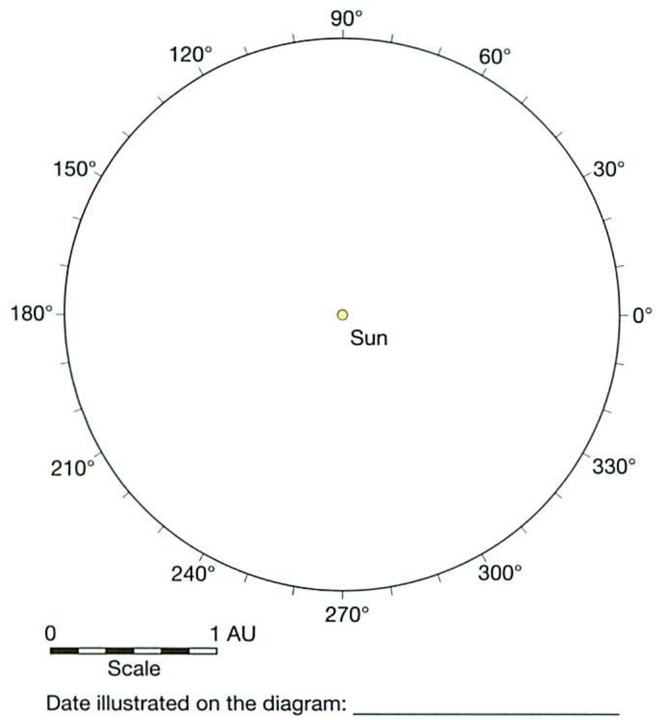

Figure 19.4 Planet locations.

2. What are the rising and setting times of each of the planets shown in Figure 19.4? Which, if any, is/are visible from Earth?

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3. What is the reason that a planet like Mars will periodically exhibit retrograde motion?

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4. Describe what is meant when a planet is said to be "in" a particular constellation.

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5. When viewed from Earth, why does the position of Saturn change only slightly from year to year?

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6. Describe the relative positions of Earth, Mars, and the Sun when Mars is best visible from Earth.

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7. Figure 19.5 illustrates the Sun, Venus, and Earth viewed from above the Northern Hemisphere of Earth. Draw an arrow around Earth showing its direction of rotation. Then, by circling your answers on the figure, indicate in which position Venus will be visible from Earth prior to sunrise and in which position it will be visible after sunset.

8. Explain why the planet Mercury is only visible slightly before sunrise and immediately after sunset.

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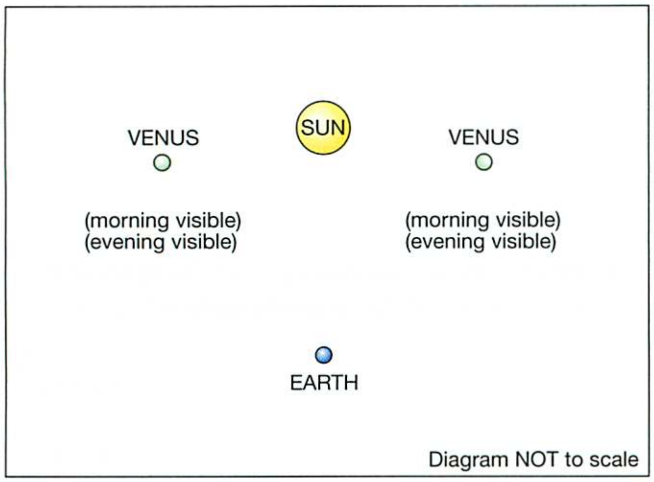

Figure 19.5 Visibility of Venus.

9. Assume Mars is rising on the eastern horizon at 9 PM CST (Central Standard Time). In the following space sketch a diagram illustrating the relative positions of the Sun, Earth, and Mars, viewed from above the Northern Hemisphere.

10. The period of rotation of Mars is about the same as the length of day on Earth. At any given moment, will the rising and setting times of the planets be the same for an observer on Mars as for an Earth-bound observer? Explain your answer.

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11. Referring to the diagram in question 9, to an observer on Mars, what will be the approximate rising and setting times for Earth?

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